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THE EFFECT UPON PERMEABILITY OF POLYVALENT CATIONS IN COMBINATION WITH POLYVALENT ANIONS

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In most of the studies carried on with a view of ascertaining how bivalent ions (such as calcium and magnesium), and trivalent ones (such as aluminum) affect permeability, the anions employed have been monovalent ones (chloride, nitrate, etc.). In studies in which *Laminaria* has been used, it has been found by Osterhout (1, 2) that wherever bivalent and trivalent cations were employed, the first effect of the salt has been to cause an increase in the resistance of the tissue (followed by a decrease), while if monovalent cations are used (with exception of acids and sodium taurocholate) the first effect is a decrease in resistance.

Since the anions, as shown in previous papers (3, 4) seem to play an important part in determining the permeability of the tissue, it seems of interest to investigate the effect of a salt composed of a polyvalent cation and a polyvalent anion.

The number of such salts which are sufficiently soluble for the present experiments is exceedingly limited, because of the pronounced relation between valency and solubility. Magnesium citrate, magnesium sulphate, and aluminum citrate were finally selected for study since they possess more than most others the requisite characteristics for this work, in respect to acidity, solubility, osmotic pressure, etc.

The solution of magnesium sulphate used was about 1.09 M and had the same conductivity as sea water. Its pH value is about 8 and it is hence only very slightly alkaline. Figure 1 (curve A) shows the average result of the six experiments performed. The probable error of the mean (as based on Peter's formula) is under 5 percent of the mean. The rise in resistance at the start is seen to be very small and temporary, and at the end of five minutes the resistance has dropped to 84 percent of the original value in sea water.

With magnesium citrate the difficulty of solubility was encountered. Since it was impossible to get a solution of the same conductivity as sea water, the practice of diluting with chloride was resorted to. When a solution composed of one sixth magnesium citrate 0.16 M and five sixths magnesium chloride 0.28 M is used, the results are as shown in figure 1, B (three experiments; probable error of the mean under 5 percent of the mean).

If this experiment is repeated, using magnesium chloride of the same electrical conductivity as the previous mixture, *viz.*, about 0.24 M, the

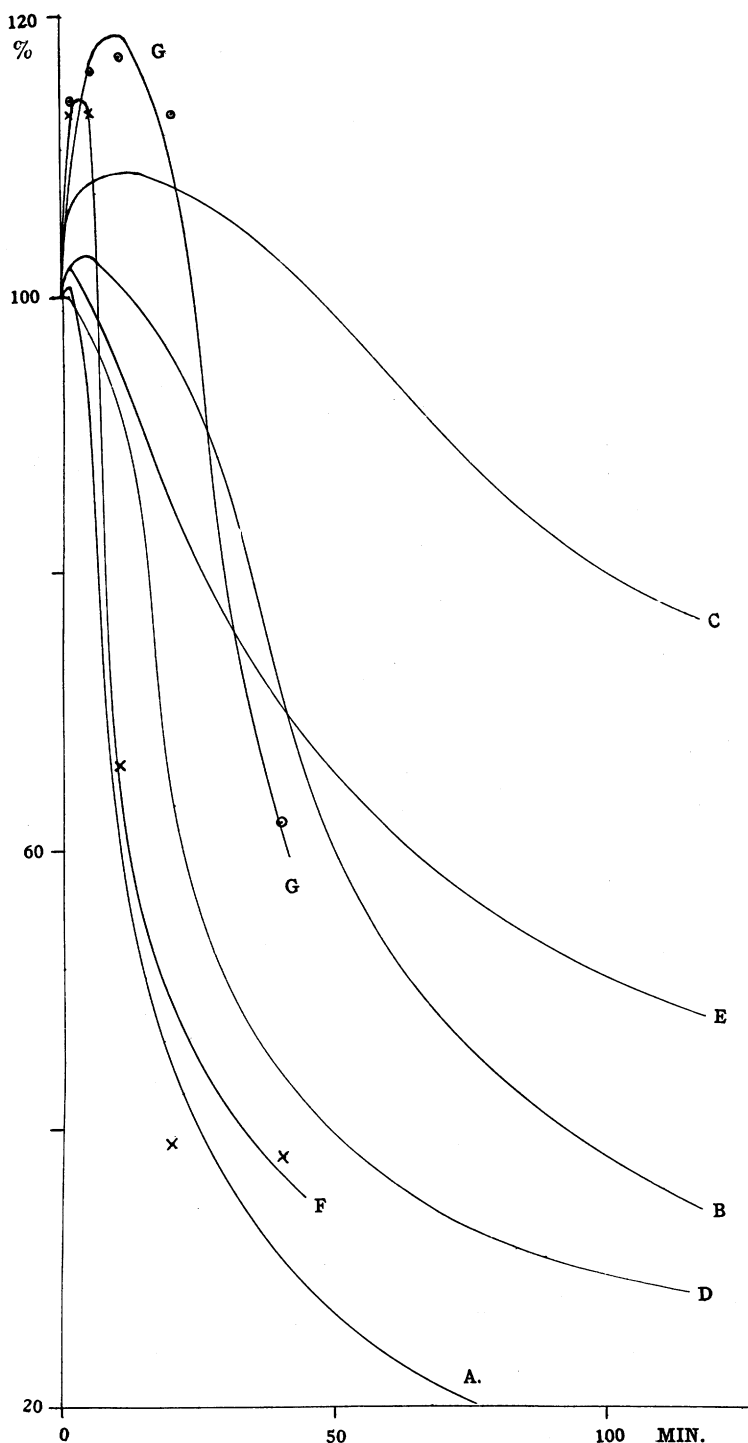


FIG. 1. Curves showing the resistance of *Laminaria* in solutions of various salts: *A*, in magnesium sulphate; *B*, in one sixth magnesium citrate and five sixths magnesium chloride; *C*, in magnesium chloride of the same conductivity as that represented by curve *B*; *D*, in one third magnesium citrate and two thirds magnesium chloride; *E*, in magnesium chloride of the same conductivity as that represented by curve *D*; *F*, in one third aluminum citrate and two thirds aluminum chloride; *G*, in aluminum chloride of the same conductivity as that represented by curve *F*. Ordinates represent resistance (expressed as percentage of the resistance in sea water, which is taken as 100 percent). Abscissae represent time in minutes.

resistance changes as shown in figure 1, *C* (three experiments; probable error less than 3 percent). It is seen that without the citrate the rise in resistance is much higher than with the citrate. In other words, the citrate has a decided tendency to keep the resistance from rising at the start.

If the proportion of citrate in the mixture is now increased from one sixth to one third, results are obtained as shown in figure 1, *D* (three experiments; probable error less than 3 percent).

A 0.20 M solution of magnesium chloride has about the same conductivity as the last mentioned solution, and if tissue is placed in it the results are as shown in figure 1, *E* (three experiments; probable error less than 5 percent). Here it is seen that the resistance rises slightly in the 0.20 M solution of magnesium chloride, but that if enough magnesium citrate is added the resistance does not increase, but decreases from the beginning. This is of interest since it shows the importance of the anion in studies on permeability.

Figure 1, *F* shows the changes in resistance in a mixture composed of two thirds aluminum chloride 0.40 M and one third aluminum citrate 1.09 M. This mixture has a pH of about 3 and the conductivity of a solution of 63 percent sea water plus 37 percent distilled water. The curve shows the average of two experiments (in which the probable error of the mean is under 3 percent of the mean).

Figure 1, *G* shows the resistance in a solution of pure aluminum chloride of the same conductivity as that represented by curve *F*. The number of experiments and the limit of probable error are also the same. The pH of this solution is about 4.

Since it is known that acid produces an initial rise in resistance, it might be thought that the acidity of the solutions is the chief factor in the effects produced. If this were true, we should expect that the greater the concentration of the citrate the greater would be the initial rise in resistance since the citrate is the more acid of the two salts, but this is just the reverse of what is found to be the case.

Again it may be suggested that in mixtures of magnesium chloride and citrate and of aluminum chloride and citrate synergetic effects are present which cause especially rapid decrease in resistance. Since pronounced synergy has been found between the chloride and citrate of sodium (5), this is quite possible. The possibility of synergetic action can not be denied, but even if it is present it is evident that the anion has a powerful influence. Moreover, the experiments with magnesium sulphate (where there is no possibility of synergetic effects) show that bivalent cations may be prevented from causing an appreciable increase in resistance if they are used with bivalent anions.

SUMMARY

Bivalent and trivalent cations in combination with monovalent anions produce an increase in the electrical resistance of *Laminaria*, but when

combined with bivalent or trivalent anions the increase is less and may be entirely lacking.

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